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Prescribed fires in *Artemisia tridentata* ssp. *vaseyana* steppe have minor and transient effects on vegetation cover and composition

Seefeldt, Steven S.[1*]; Germino, Matthew[2,3] & DiCristina, Katherine[2,4]

[1]*United States Department of Agriculture, Agricultural Research Service, Subarctic Agricultural Research Unit, Room 355 O'Neill Building, University of Alaska Fairbanks, Fairbanks, AK 99775, USA;*
[2]*Department of Biological Sciences, Idaho State University, Pocatello, ID 83209, USA ;* [3]*E-mail germmatt@isu.edu;*
[4]*E-mail katiedi@hotmail.com;* [*]*Corresponding author; Fax+1 9074746521; E-mail sseefeldt@pw.ars.usda.gov*

Abstract

Question: What is the impact of prescribed fires on the cover and composition of vegetation in *Artemisia tridentata* ssp. *vaseyana* steppe?

Location: United States Department of Agriculture, Agricultural Research Service, United States Sheep Experiment Station, eastern Idaho (44°14'44" N, 112°12'47" W).

Methods: Multiple prescribed fires were lit in 2002 and 2003 in an *Artemisia tridentata* ssp. *vaseyana* (mountain big sagebrush) steppe ecosystem that was relatively free of exotic plants. Measurements of cover components and plant species frequencies were taken pre- and for 2 to 3 years post-fire.

Results: Cover of forbs and grasses returned to pre-fire levels after two years. Shrub cover declined from 36 to 6% in the first year post-fire. Fire reduced the frequencies of three species, *A. tridentata* ssp. *vaseyana*, *Festuca idahoensis*, and *Cordylanthus ramosus*, of rangeland plants. Frequencies of four plant species, *Hesperostipa comata*, *Polygonum douglasii*, *Chenopodium fremontii* and *Chenopodium leptophyllum* increased, but only *P. douglasii* increased for more than a year.

Conclusion: This study demonstrates that in an *Artemisia tridentata* ssp. *vaseyana* steppe ecosystem without significant non-native species or anthropogenic disturbances vegetative cover and species composition of the herbaceous community are only minimally altered by fire. The herbaceous component returned to pre-fire conditions within three years of a fire.

Keywords: Plant diversity; Plant frequency; Plant succession; Sagebrush.

Abbreviations: ARS = Agricultural Research Service; USDA = United State Department of Agriculture; USSES = United States Sheep Experiment Station.

Nomenclature: USDA Natural Resources Conservation Service, Plants database http://plants.usda.gov/

Introduction

Wildfire is a natural part of the *Artemisia tridentata* (big sagebrush) steppe ecosystem (Blaisdell et al. 1982) with fire-free intervals before European settlement varying from 20 to 25 years (Burkhardt & Tisdale 1976) or 12 to 15 years (Miller & Rose 1999) in *Artemisia tridentata* ssp. *vaseyana* steppe communities. In a Clementsian model of vegetation change following fire developed in west-central Utah (Barney & Frischknecht 1974), fire in the sagebrush steppe restarts plant succession, which begins with an annual weedy stage that is followed by a perennial grass/forb stage 3 or 4 years post-fire. Subsequent stages of succession include dense sagebrush potentially followed by invasive pinyon-juniper woodland (Miller et al. 2005). Dense sagebrush stands (cover > 30%) are associated with declines in plant diversity and increased fire risk (Johnson et al. 1996). Additionally, dense sagebrush stands typically have decreased forage production of perennial grasses and forbs (Harniss & Murray 1973; Bork et al. 1998).

Consequently, as a sagebrush stand increases in age, the succession of plants post-fire will be potentially altered. Recent research has measured altered succession post-fire due to the influence of exotic, invasive weeds that has resulted in increased fire frequency (Pellant 1990; Whisenant 1990). This and other observed alterations, such as reduced sagebrush populations and increased invasive weed populations, have resulted in the development of state and transition models of plant succession (Laycock 1991; Stringham et al. 2003). It is important to know the condition (state) of the vegetation pre-fire in order to predict plant succession (transition) post-fire. With few exceptions (Harniss & Murray 1973), most research conducted on vegetation recovery post-fire has been initiated after the fire with little or no information on pre-fire vegetation (Barney & Frischknecht 1974; Wambolt et al. 2001; Wrobleski & Kauffman 2003). To properly test state and transition models, knowledge of vegetation conditions before disturbance is critical.

Few areas of sagebrush steppe in Snake River Plain are both relatively free of exotic plants and available for prescribed fires. At the USDA-ARS-USSES two areas that have only been lightly grazed by sheep and have a very low density of exotic plants (small patches of *Verbascum thapsus* on rock outcrops and trace amounts of *Taraxacum officinale* and *Bromus tectorum*) were selected to measure the influence of fire on vegetation cover and composition.

The objectives of this study were to determine vegetation change post-fire in an ecosystem relatively free of exotic plants and to determine whether time since last fire influenced post-fire vegetation composition and dynamics. The results of this study will provide a baseline for subsequent prescribed fires in areas of the sagebrush steppe with vegetation communities that have larger invasive plant components. Our hypotheses are that fire in a healthy intact stand of vegetation in an ecosystem that evolved with fire has only transient effects on the herbaceous vegetation component and that post-fire vegetation is dependent on pre-fire vegetation.

Material and Methods

In the summer of 2001, an area in the northeast corner of the USSES headquarters grazing range (44°14'44" N, 112°12'47" W) with a 34 to 42% shrub cover was selected for a prescribed burn (Fig. 1). The site, at an elevation of 1800 m, is in the northeastern portion of the sagebrush steppe region in the western United States (West 1983). Soils are fine-loamy, mixed, frigid Calcic Argixerolls derived from windblown loess, residuum, or alluvium on slopes ranging from 0 to 12% (Anon. 1995). Climate is semi-arid with cold winters. Several months have mean temperatures below freezing, and warm summers with daily highs averaging 27 °C. During the study, precipitation amounts were 232, 188, 236, 339 and 390 mm from 2001 to 2005, respectively. Annual precipitation averages 330 mm, with up to 60% falling in the winter as snow. The vegetation type was *Artemisia tridentata* ssp. *vaseyana* with *Festuca idahoensis*.

Two sets of fires (2002 and 2003) were located on two 260 ha parcels of land that were sheep grazed for the last 20 years. Sheep grazing typically occurred for one week each spring and fall with an average yearly stocking density of 40 sheep days ha^{-1}. The land was not grazed the year before the fires. The southern two thirds of the 2002 site and the entire 2003 site burned in

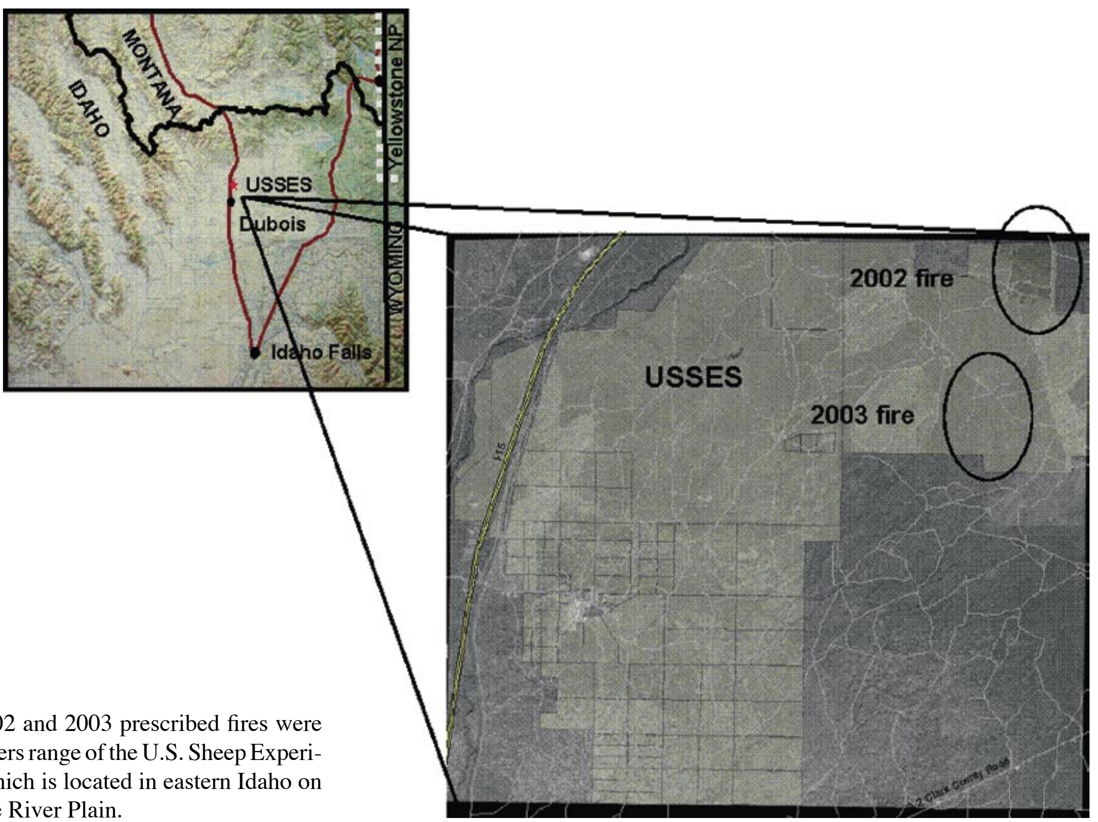

Fig. 1. Both 2002 and 2003 prescribed fires were on the headquarters range of the U.S. Sheep Experiment Station, which is located in eastern Idaho on the Upper Snake River Plain.

1981. The northern third of the 2002 site last burned in 1960 (Fig. 1).

For each fire, two fire lines were constructed using a road grader in June of the burn year. One fire line encompassed a 260-ha area and the other isolated approximately 100-ha within the larger area for the single largest burn. The vegetation was burned over a two day period in September using standard prescribed fire techniques for the sagebrush steppe.

Measurements of vegetation cover and plant frequency were taken at 100 permanent plots pre- and post-fire in 2002 and at 25 plots pre- and post-fire in 2003. Plot locations were determined using GIS and GPS to fully stratify and evenly disperse sampling locations. Treatment areas were burned or unburned with 50 unburned and 41 burned plots in 2002 and 5 unburned and 20 burned plots in 2003. The study was replicated with prescribed fires in 2002 and 2003. At each plot a nested frequency quadrat frame (0.45 m^2) was placed in an area that was representative of the vegetation. Nails were used to mark opposite corners of the frame for precise measurements after the fires. Cover of shrubs, grasses, and forbs were estimated visually in the plot area. Species frequency and cover estimates were measured in July of 2002, 2003, 2004, and 2005.

Data from the 2002 and 2003 fires were analysed separately. The data were determined to be normally distributed using a UNIVARIATE procedure on model residuals with the Shapiro-Wilk statistic (SAS Inst. Inc., Cary, NC, US). Cover was analysed using a repeated measures analyses of variance (MANOVA) to examine the relationship between time since fire and percent cover of each class (forb, grass, and shrub) in burned and unburned plots within each year. An ANOVA with paired contrasts between each set of consecutive years was used to determine changes in percent cover between years for burned and unburned plots separately (SAS Inst. Inc., Cary, NC). The same analyses were used within burned plots from the 2002 fire to determine if time before last historic fire (21 or 42 year) impacted vegetation recovery.

In order to analyse for differences in plant species frequency in 2002, only species that were in 30% or more of all sample plots (burned and unburned plots combined) could be used (19 of 70 species) to satisfy assumptions of normality. Therefore, we selected quadrat sizes (110, 870, 2210, or 4420 cm^2) independently for each species based on frequency percentages consistently nearest 50% for all years in burned and unburned plots (Stephen Bunting, personal communication). Presence/absence data were tallied for the chosen quadrat size for each species. For each species, $2 \times 2\ \chi^2$ analyses with McNemar's test (SAS Inst. Inc., Cary, NC, US) were used to assess differences in frequencies between pairs of consecutive years for burned and unburned plots. If species were absent from at least one year of the paired comparisons, a statistical determination could not be made; however, the loss of a species was noted. Differences were considered significant when the *F*-test probability was ≤ 0.05. The 2003 plant species frequency analyses were not conducted due to insufficient replication (Zar 1974).

Results

Both 2002 and 2003 fires burned more than 95% of the area and removed more than 95% of the vegetation biomass in the burned areas (visual observation). The fires were classified as low severity (Hungerford 1996) as the surface was largely black with some isolated pockets of gray ash. In both fires, soil temperatures remained below 40 °C at 0.5 cm depth based on over 100 passive temperature sensors in the 2002 fire and temperature measurements with Campbell data loggers in the 2003 fire (unpubl. data).

Cover of vegetation classes

Before the fire in 2002, all cover components were similar between plots that were to be burned or unburned. Before the fire in 2003, all cover components were similar except for forbs ($P = 0.01$) where the area to be burned averaged 16% forbs and the area that was not burned averaged 4% forbs.

There were statistical differences in grass, forb, and shrub cover due to fire, time, and the interaction of fire and time. For the 2002 fire, grass cover (Fig. 2a) was greater in the burned area compared to the unburned over the course of the experiment ($P = 0.03$), and there was an interaction of time and burn ($P < 0.0001$). Grass cover in the burned area declined in the year following fire and increased to pre-fire levels in the second and third year after the fire. In the unburned area, grass cover did not change the first year post-fire, declined in the second year, and did not recover in the third year. There was more grass cover in the unburned area one year post-fire compared to the burned, but there was more grass cover in the burned area in second and third year compared to the unburned. In the 2003 fire, grass cover did not differ between burned and unburned areas (Fig. 2b). However, grass cover declined ($P = 0.006$) the first year post-fire and increased ($P = 0.05$) in the second year post-fire.

The 2002 fire did not change forb cover ($P = 0.88$) over the course of the experiment between the burned and unburned treatments (Fig. 2c). However, forb cover changed with time ($P < 0.0001$) and there was an interaction with time and fire ($P = 0.0003$). In the first year post-fire, there were more forbs in the unburned area

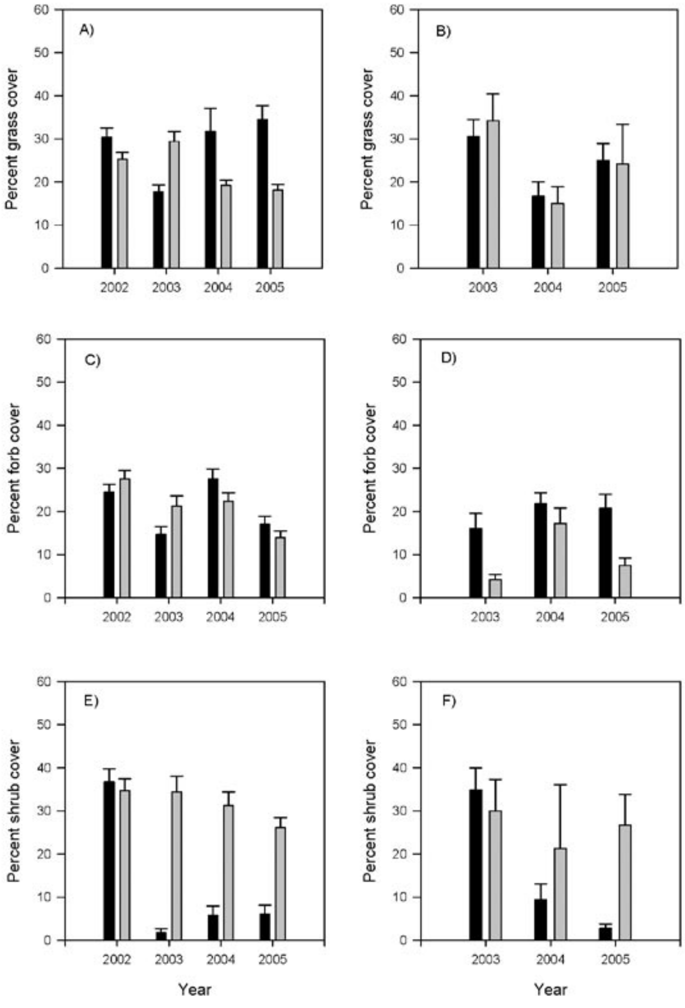

Fig. 2. Cover components of burned (dark bars) and unburned (light bars) areas. Prescribed fires at the U.S. Sheep Experiment Station occurred after initial vegetation measures in 2002 (**A**, **C**, **E**) and 2003 (**B**, **D**, **F**). Error bars are the standard error.

($P = 0.03$) compared to the burned area and forb cover declined in both burned ($P = 0.0005$) and unburned areas ($P = 0.02$). Forb cover increased ($P < 0.0001$) in the burned area in the second year compared with the first year post-fire, and forb cover decreased in burned ($P = 0.0002$) and unburned ($P = 0.003$) areas in the third year post-fire. In the 2003 fire, forb cover one year post-fire was similar in the burned and unburned areas, and forb cover increased ($P = 0.01$) in the unburned area (Fig. 2d). In the second year post-fire, forb cover declined in the unburned area ($P = 0.03$) and was less than in the burned area ($P = 0.01$). Over the course of the study, forb cover was greater ($P = 0.01$) in the burned compared to the unburned area, and forb cover in the burned area did not change.

Fire reduced ($P < 0.0001$) shrub cover in both the 2002 and 2003 fires (Fig. 2e and 2f). The fire reduced shrub cover from 37 to 2% in the 2002 fire and 35 to 9% in the 2003 fire the year after the burns. In the 2002 fire, each year post-fire, shrub cover was less in the burned than unburned areas ($P < 0.0001$). In the 2003 fire, shrub cover in the burned and unburned areas was not different until the second year post-fire ($P < 0.0001$). Shrub cover did not change in the unburned areas during the course of the study in both the 2002 and 2003 fires. Shrub cover in the burned area did not change after the initial decline caused by the fire for both 2002 and 2003 fires.

Time since the last historic fire (21 or 42 years) did not affect vegetation cover components after the 2002 fire.

Plant species frequencies

Based on the frequency plots analysed at the 870 cm^2 nested area, the two most common species were the perennial grasses *Poa secunda* and *Elymus albicans*. Plants analysed at the 2210-cm^2 nested area were perennial grasses *Festuca idahoensis* and *Koeleria macrantha*, perennial forb *Erigeron corymbosus*, and annual forb *Polygonum douglassii*. The remaining plants were ana-

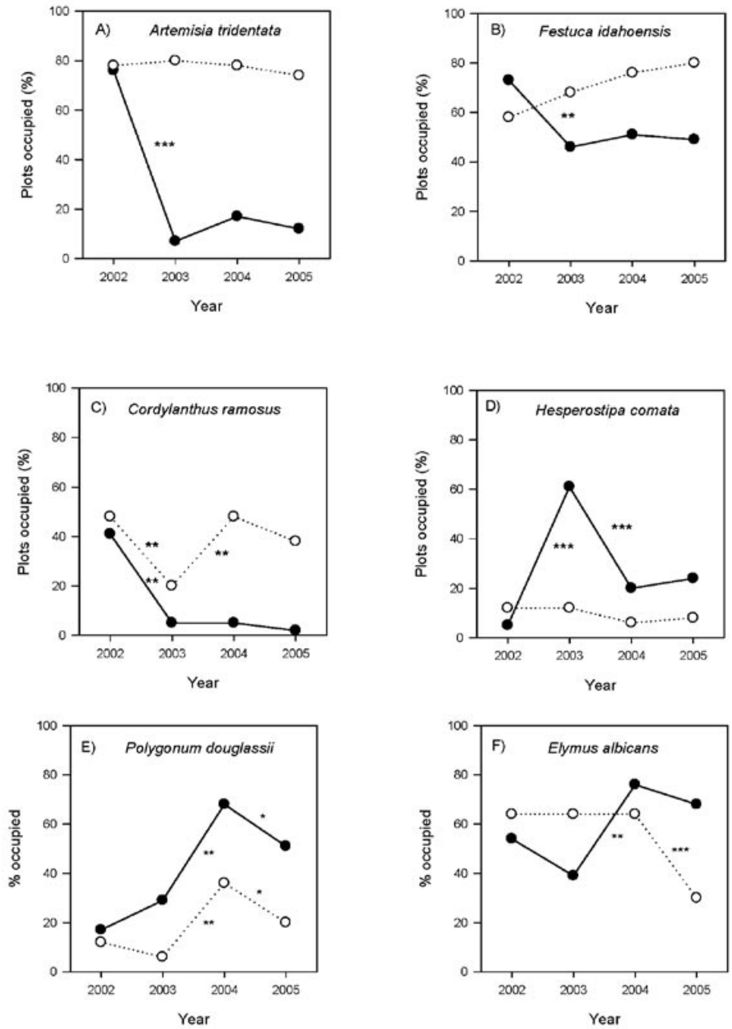

Fig. 3. Plant species frequencies in burned (solid line) and unburned (dashed line) areas. Prescribed fires at the U.S. Sheep Experiment Station occurred after initial vegetation measures in 2002 (**A**, **C**, **E**) and 2003 (**B**, **D**, **F**).

lysed at the nested area of 4420 cm^2.

Of the 19 plant species analysed for frequency, three (*Artemisia tridentata* spp. *vaseyana*, *Festuca idahoensis*, and *Cordylanthus ramosus*) declined and two (*Hesperostipa comata* and *Polygonum douglassii*) increased in the burned area (Fig. 3a-e). *H. comata* frequencies increased to 60% in the year following the 2002 fire in the burned plots representing a flush of new plants, but then declined to near unburned amounts in 2004 (Fig 3e). *P. douglassii*, an annual forb, increased in the second year and declined the third year post-burn in both burned and unburned areas in the 2002 fire area. The size of the *P. douglassii* increase, however, was larger in the burned plots. In the 2003 fire, *P. douglassii* appeared in both burned and unburned areas after the fire. Two other annual forb species (*Chenopodium fremontii* and *Chenopodium leptophyllum*) that could not be analysed due to lack of sufficient numbers each year, apparently increased as a response to the burn (Apps. 1 and 2). *C. fremontii* appeared in 2004 in both burn areas (8 and 4 plots in the 2002 and 2003 burns, respectively) and then declined in 2005 (1 plot each in the 2002 and 2003 burns, respectively). *C. leptophyllum* appeared the year after each fire (17 and 8 plots in the 2002 and 2003 burns, respectively) and then declined the following year (4 and 0 plots in the 2002 and 2003 burns, respectively). In the 2003 fire, 3 of the 5 plots in the unburned area had *C. leptophyllum*.

Elymus albicans was abundant before the 2002 burn (Fig. 3f and App. 1). Two years post-fire, its frequency increased in the burned areas. Three years post-fire, its frequency decreased in the unburned areas. In the 2003 burn, there were no *E. albicans* plants in the plots (App. 2) however, one year post-fire, frequencies increased in the burned and unburned areas to 80%.

Responses to the 2002 fire were similar in the burned and unburned areas for *Viola nuttallii*, *Microseris nutans*, *Mertensia oblongifolia*, *Poa secunda*, *Koeleria macrantha*, *Allium acuminatum*, *Gayophytum racemosum*, *Carex filifolia*, *Astragalus miser*, *Antennaria rosea*, *Astragalus convallarius*, *Eriogonum heracleoides*, and *Erigeron* *corymbosus* (data not shown). For each species, changes in frequency between the burned and unburned plots were largely parallel, reflecting natural background variability. Perennial forbs *Viola nuttallii* and *Microseris nutans* were only observed in abundance in 2004 in the burned and unburned plots, and *Mertensia oblongifolia*, another perennial forb, disappeared in both the burned and unburned areas in 2005. Frequencies of *Poa secunda* and *Koeleria macrantha* increased over time. Frequencies of *Allium acuminatum*, a perennial forb, and *Gayophytum racemosum*, an annual forb, increased in 2004. The remaining plant species remained relatively stable during the course of the study. Generally, responses of the above plant frequencies in the 2003 fire are similar to the 2002 fire, but there were some exceptions. *A. convallarius*, *C. filifolia*, and *A. miser* all had potentially significant increases in frequency in the burned area compared to the unburned.

Discussion

Because of the pre-fire plant measurements, it was possible to separate vegetation changes as a result of fire from vegetation changes independent of fire, therefore comparing vegetation in burned and unburned areas in light of natural change.

Cover components

Although vegetation cover decreased initially in burned areas the first year post-fire, forbs and grass returned to or exceeded pre-fire levels after 2 years (Fig. 2). These results are consistent with previous studies (Harniss & Murray 1973; Barney & Frischknecht 1974) that reported vegetation in the first years post-fire being dominated by grasses and forbs. In both the 2002 and 2003 study sites, grass cover declined in 2004 in the unburned areas as a response to other biotic and abiotic factors. Grass cover increased in 2004 in the 2002 burn site (Fig. 2a) indicating these factors did not impact the grass component equivalently. The decline in grass cover in the burned area the year after the 2003 fire (Fig. 2b) matched the grass cover decline in the unburned area. There was not an enhanced decline in grass cover due to the fire in combination with other biotic and abiotic factors. Except for shrub cover, the fires had only transient impacts on cover components.

An objective of this study was to determine whether time since last fire impacted subsequent vegetation. In this study, time since the last fire (21 or 41 years) did not have an impact on recovery of vegetation cover after fire. Although individual shrub species seemed larger and woodier, all the cover components were the same as pre-fire in the two age classes; therefore, it was not surprising to measure similar recoveries. Thus, it appears that there is a sizable time span (at least 20 years) where vegetation recovery will be similar after fire in this area as long as the pre-fire vegetation components are similar.

Plant species frequencies

Another objective of this study was to determine the response of plant species to fire in the sagebrush steppe. Plant populations respond to a variety of biotic and abiotic influences such as grazing (West et al. 1979), drought (Pechanec et al. 1937), fire (Harniss & Murray 1973), and fire severity (Bates et al. 2006), and each plant species' response may be independent or dependent on the other species around it (West et al. 1979). Although fire was the treatment applied in this study, the responses of plant species to the fire were affected by interactions with other biotic and abiotic factors such as the increased rainfall in 2004 and 2005.

Of the species that declined due to fire, *A. tridentata* spp. *vaseyana*, the dominant shrub in this ecosystem, does not sprout back after a fire and few seedlings were observed. Based on earlier studies, over the next 15 to 20 years this shrub species should re-establish and dominate the site (Harniss & Murray 1973). Three other shrub species, *Chrysothamnus viscidiflorus*, *Tetradymia canescens*, and *Purshia tridentata* are known to increase after fire due to their sprouting ability (Harniss & Murray 1973). Because of their small populations on these sites, we did not detect any increases in frequency or number.

Over one third of the *F. idahoensis* plants, a perennial grass species, were killed during the 2002 and 2003 prescribed burns. This decline in frequency has also been observed in others studies (Blaisdell 1953; Conrad & Poulton 1966; Schwecke & Hann 1989; Wambolt et al. 2001). *F. idahoensis* frequency did not increase in the second and third year after the fire and may take several decades to fully recover (Harniss & Murray 1973). This data supports the findings of Wright & Klemmedson (1965) that the perennial grass *Hesperostipa comata* (Fig. 3d) is resistant to fire, especially when the fire occurs after August. *E. albicans* is a rhizomatous grass species that typically responds positively after fire (Harniss & Murray 1973; Akinsoji 1988). However, in this study the response was mixed (Fig. 3f). In the burn area of the 2002 fire *E. albicans* response was delayed a year and in the 2003 fire, the positive response was similar in the burned and unburned areas. For this species, it may be that the increase and timing of rainfall had more to do with its positive growth in 2004 than did the prescribed fire or that a positive fire response is contingent on precipitation. Because of the low intensity of the fire, all other perennial grass and forb species frequencies were minimally impacted by the fire. Both fires occurred in relatively dry years, which may have reduced seed production, resulting in minimal recruitment of new plants.

There was an expectation that annual plants would increase in frequency immediately after the fire (Harniss & Murray 1973; Barney & Frischknecht 1974). Indeed, *Polygonum douglassii* (Fig. 3e), and two *Chenopodium* species increased as a response to the 2002 fire. However, *Cordylanthus ramosus*, a late season annual forb common in the region and not grazed by cattle or sheep, nearly disappeared in the burned areas after the 2002 and 2003 burns. Other studies have measured similar short-duration positive responses of *Chenopodium* species to fire (Bartos & Mueggler 1981; Bartos et al. 1994).

The remaining species that were analysed responded similarly in the burned and unburned areas. Any responses in these species were possibly due to some other biotic or abiotic factor or, more probably, an interaction of factors. Although frequencies of *Eriogonum heracleoides* and *Erigeron corymbosus* did not vary in this study, or in a 1952 fire in southeast Idaho, there was a reported increase in the biomass of these two species three years post-fire (Mueggler & Blaisdell 1958).

Some increases and decreases of plant species following fire have been reported in earlier studies; however few of these studies have measured pre-fire vegetation. The response to fire of many of the species in this study has not been reported in the scientific literature. Of particular interest are the perennial grasses *Poa secunda* and *Koeleria macrantha*, which both increased in frequency after the 2002 and 2003 fires. The increases in frequency were dependent on year, 2004 for *P. secunda* and 2005 for *K. macrantha*, and apparently independent of fire. These results for *P. secunda* are consistent with the measurements of Wright & Klemmedson (1965). However the results for *K. macrantha* are different from Antos et al. (1983) which showed increases restricted to burned areas.

There were 70 and 53 species observed in the 2002 and 2003 studies, respectively. Of these, only three species had decreased and four had increased frequencies. The first year after both fires there were decreases in grass and shrub cover. In the second year after the fires, grass cover had increased to pre-fire levels in the burned areas, whereas shrub cover can take decades to return to pre-fire amounts.

Wildfire is a natural part of the sagebrush steppe ecosystem (Blaisdell et al. 1982). This study demonstrates that in a sagebrush steppe ecosystem, without significant non-native species or anthropogenic disturbances, herbaceous species composition is only minimally altered after fire, and the plant community that develops several years post-fire is similar to the one pre-fire. Moreover initial sagebrush recovery indicates that the vegetation most likely will return to a sagebrush dominated community as standard Clementsian models describe (Harniss & Murray 1973; Barney & Frischknecht 1974; Wambolt et al. 2001). In drier sagebrush steppe ecosystems, where fire might be less frequent naturally, or in areas with more disturbance or more non-native plants, vegetation recovery from fire may take a different trajectory (Pellant 1990; Whisenant 1990). Based on the findings of this study, a late season fire occurring in an intact 20 to 40 year old native stand of *Artemisia tridentata* ssp. *vaseyana* will minimally impact the vegetation and the impacts will be transient. More importantly the findings of this study indicate that the herbaceous community post-fire is tightly linked to the pre-fire community. This research supports the larger hypothesis that if an ecosystem evolved with periodic wildfire, then the normal vegetation of the ecosystem will recover quickly and positively to appropriately timed fires.

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For App. 1 and 2, see JVS/AVS Electronic Archives; www.opuluspress.se/

App. 1. Plant species frequencies determined in the 2002 burn area from 50 unburned and 41 burned plots at the U.S. Sheep Experiment Station, eastern Idaho.

Species	Treatment	2002	2003	2004	2005
			————Frequency————-		
Annual forbs					
Amsinckia menziesii	Burned	0	1	0	0
Chenopodium fremontii	Burned	0	0	8	1
Chenopodium leptophyllum	Burned	0	17	4	0
Collinsia parviflora	Burned	7	5	7	0
	Unburned	9	7	8	0
Cordylanthus ramosus	Burned	17	2	2	1
	Unburned	24	10	24	19
Gayophytum racemosum	Burned	0	4	19	1
	Unburned	2	2	10	3
Lepidium densiflorum	Burned	0	0	0	2
Polygonum douglasii	Burned	8	18	34	26
	Unburned	7	4	21	14
Tragopogon dubius	Burned	0	0	1	0
	Unburned	2	1	1	2
Perennial forbs					
Achillea millefolium	Burned	7	6	7	9
	Unburned	12	15	17	15
Agoseris glauca	Burned	2	0	1	0
	Unburned	1	0	2	0
Allium acuminatum	Burned	13	7	19	16
	Unburned	18	1	14	12
Antennaria dimorpha	Burned	0	0	1	0
	Unburned	0	0	1	0
Antennaria rosea	Burned	21	16	19	12
	Unburned	30	30	29	29
Antennaria umbrinella	Burned	0	0	1	0
	Unburned	0	0	1	0
Arabis holboellii	Burned	1	0	0	0
Arenaria kingii	Burned	0	0	1	0
	Unburned	1	0	3	0
Arnica fulgens	Burned	6	2	5	0
	Unburned	6	6	9	1
Astragalus convallarius	Burned	14	16	11	16
	Unburned	15	14	13	7
Astragalus filipes	Burned	0	3	0	0
	Unburned	0	1	0	0
Astragalus lentiginosus	Burned	1	1	2	0
Astragalus miser	Burned	9	10	13	6
	Unburned	9	4	10	6
Calochortus macrocarpus	Burned	0	0	0	1
	Unburned	0	0	0	1
Cirsium undulatum	Burned	4	1	1	1
	Unburned	3	2	2	2
Comandra umbellata	Burned	0	0	3	2
	Unburned	0	0	6	3
Crepis acuminata	Burned	1	0	5	2
	Unburned	0	0	2	1
Erigeron corymbosus	Burned	28	27	29	27
	Unburned	27	26	28	28
Erigeron filifolius	Burned	0	1	0	0
	Unburned	0	1	1	0
Eriogonum heracleoides	Burned	20	14	15	17
	Unburned	15	16	18	21
Erigeron pumilus	Unburned	0	0	1	0
Lomatium foeniculaceum	Burned	0	0	1	0
	Unburned	1	0	1	1
Lomatium triternatum	Burned	2	0	6	0
	Unburned	1	0	5	0
Lupinus caudatus	Burned	3	3	4	5

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App. 1, cont.

Species	Treatment	2002	2003	2004	2005
			————Frequency————-		
	Unburned	4	5	5	13
Mertensia oblongifolia	Burned	6	12	19	0
	Unburned	4	8	19	0
Microseris nutans	Burned	4	0	13	0
	Unburned	6	0	15	0
Penstemon deustus	Burned	0	1	0	0
	Unburned	0	1	1	0
Penstemon radicosus	Burned	2	1	3	3
	Unburned	0	0	1	0
Phlox hoodii	Unburned	0	0	3	1
Phlox longifolia	Burned	4	14	16	7
	Unburned	10	10	18	6
Potentilla gracilis	Unburned	2	2	2	2
Ranunculus glaberrimus	Unburned	0	1	0	0
Schoenocrambe linifolia	Burned	0	0	1	0
Senecio integerrimus	Burned	0	0	1	0
	Unburned	0	0	1	0
Sphaeralcea munroana	Burned	0	2	0	0
Stenotus acaulis	Unburned	1	1	0	0
Taraxacum officinale	Burned	0	0	1	1
	Unburned	0	0	1	0
Tragopogon dubius	Burned	0	0	1	0
	Unburned	2	1	1	2
Verbascum thapsus	Burned	0	0	1	1
	Unburned	1	1	0	0
Viola beckwithii	Burned	2	1	5	0
	Unburned	5	2	6	0
Viola nuttallii	Burned	0	0	12	0
	Unburned	1	0	20	0
Perennial grasses					
Achnatherum nelsonii	Burned	0	0	0	3
	Unburned	0	0	0	5
Calamagrostis montanensis	Burned	0	12	1	0
	Unburned	0	0	1	0
Carex filifolia	Burned	16	12	17	18
	Unburned	8	8	11	21
Elymus albicans	Burned	29	20	36	36
	Unburned	43	40	38	24
Festuca idahoensis	Burned	31	22	23	25
	Unburned	36	39	43	46
Hesperostipa comata	Burned	2	25	8	10
	Unburned	6	6	3	4
Koeleria macrantha	Burned	0	2	3	25
	Unburned	4	6	4	22
Poa secunda	Burned	15	20	33	34
	Unburned	28	23	38	37
Pseudoroegneria spicata	Burned	0	0	4	6
	Unburned	3	1	5	3
Perennial shrubs					
Amelanchier alnifolia	Burned	0	0	0	1
	Unburned	0	0	0	1
Artemisia tridentata	Burned	31	3	7	5
	Unburned	39	40	39	37
Chrysothamnus viscidiflorus	Burned	2	4	5	5
	Unburned	2	2	1	3
Mahonia repens	Burned	2	1	1	1
	Unburned	3	3	3	3
Opuntia polyacantha	Unburned	1	0	1	1

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App. 1, cont.

Species	Treatment	2002	2003	2004	2005
			————Frequency————-		
Purshia tridentata	Burned	6	3	7	6
	Unburned	2	4	3	3
Rosa woodsii	Unburned	1	1	1	0
Symphoricarpos oreophilus	Burned	1	2	1	1
	Unburned	2	3	1	0
Tetradymia canescens	Burned	3	6	4	5
	Unburned	5	6	5	7
Tree					
Larix occidentalis	Burned	1	0	9	0
	Unburned	0	0	2	0
Unknown					
	Unburned	0	0	1	0

App. 2. Plant species frequencies determined in the 2003 burn area from 5 unburned and 20 burned plots at the U.S. Sheep Experiment Station, eastern Idaho.

Species	Treatment	2003	2004	2005
			——Frequency——-	
Annual forbs				
Chenopodium fremontii	Burned	0	4	1
Chenopodium leptophyllum	Burned	0	8	0
	Unburned	0	3	0
Collinsia parviflora	Burned	2	8	1
	Unburned	0	0	1
Cordylanthus ramosus	Unburned	2	2	3
Gayophytum racemosum	Burned	1	3	1
	Unburned	0	2	0
Lepidium densiflorum	Burned	0	2	3
Polygonum douglasii	Burned	0	10	13
	Unburned	0	4	3
Tragopogon dubius	Burned	0	1	0
Annual grasses				
Bromus tectorum	Burned	2	3	1
Perennial forbs				
Achillea millefolium	Burned	5	5	3
	Unburned	1	1	3
Agoseris glauca	Burned	0	1	0
	Unburned	0	1	0
Allium acuminatum	Burned	1	3	14
	Unburned	0	1	2
Antennaria dimorpha	Burned	0	1	0
	Unburned	0	1	0
Antennaria rosea	Burned	4	3	3
	Unburned	0	1	1
Arabis holboellii	Burned	0	1	0
Arenaria kingii	Unburned	0	0	1
Arnica fulgens	Burned	0	6	1
	Unburned	0	1	0
Astragalus convallarius	Burned	4	5	3
	Unburned	1	1	2
Astragalus filipes	Burned	2	0	0
Astragalus miser	Burned	0	5	3
	Unburned	0	2	1
Astragalus purshii	Burned	0	1	0
Calochortus macrocarpus	Burned	0	3	4

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App. 2, cont.

Species	Treatment	2003	2004 — —Frequency— —-	2005
	Unburned	0	1	1
Cirsium undulatum	Burned	3	0	1
Collomia linearis	Burned	1	0	0
Comandra umbellata	Burned	3	5	6
	Unburned	1	2	1
Crepis acuminata	Burned	3	5	8
	Unburned	1	1	1
Erigeron corymbosus	Burned	8	4	8
	Unburned	4	2	3
Erigeron filifolius	Burned	0	0	1
Eriogonum heracleoides	Burned	16	9	9
	Unburned	4	5	3
Lomatium foeniculaceum	Burned	0	0	2
	Unburned	0	0	1
Lupinus caudatus	Burned	2	3	4
	Unburned	2	2	1
Mertensia oblongifolia	Burned	0	1	0
	Unburned	0	1	0
Penstemon radicosus	Burned	0	1	1
	Unburned	0	1	1
Phlox longifolia	Burned	11	8	8
	Unburned	3	2	2
Sphaeralcea munroana	Burned	0	1	0
Taraxacum officinale	Burned	0	3	3
	Unburned	0	1	2
Viola nuttallii	Burned	0	1	0
Perennial grasses				
Achnatherum nelsonii	Burned	0	2	0
Calamagrostis montanensis	Burned	0	1	0
	Unburned	0	1	0
Carex douglasii	Burned	0	1	0
Carex filifolia	Burned	0	2	4
	Unburned	0	2	0
Elymus albicans	Burned	0	17	16
	Unburned	0	4	4
Festuca idahoensis	Burned	10	7	2
	Unburned	1	3	1
Hesperostipa comata	Burned	9	5	6
	Unburned	3	1	3
Koeleria macrantha	Burned	1	2	13
	Unburned	2	0	2
Leymus cinereus	Burned	1	2	1
	Unburned	0	1	0
Poa secunda	Burned	10	9	12
	Unburned	3	3	5
Pseudoroegneria spicata	Burned	0	0	1
	Unburned	0	2	0
Perennial shrubs				
Artemisia tridentata	Burned	16	7	3
	Unburned	5	3	5
Chrysothamnus viscidiflorus	Burned	3	5	4
Opuntia polyacantha	Burned	1	0	0
Purshia tridentata	Burned	1	0	0
Tetradymia canescens	Burned	4	1	3
	Unburned	1	1	1